# Save Energy Now in High Performance Computer Centers

## CEE Field Trip
## January 13, 2009


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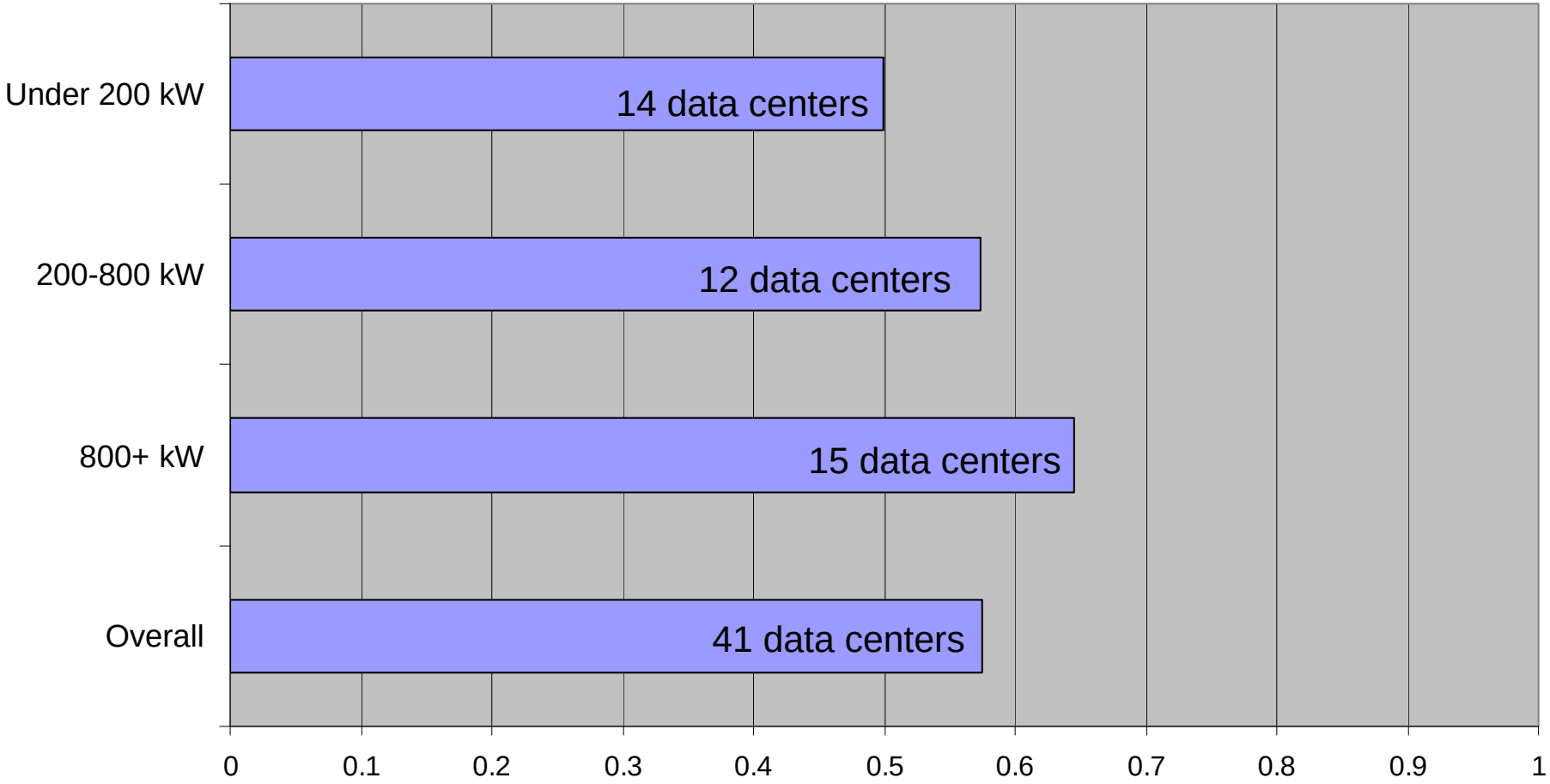
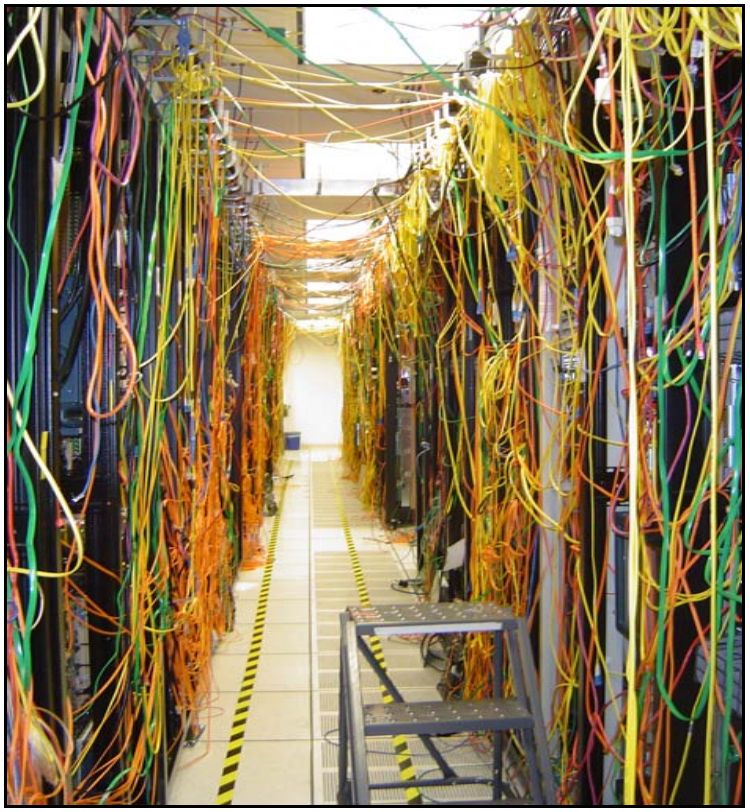
# Average Data Center Infrastructure Efficiency (DCiE) for DOE Data Centers



# Using benchmark results to find best practices:

- **Air management**
- Right-sizing
- Central plant optimization
- Efficient air handling
- **Liquid cooling**
- **Free cooling**
- **Humidity control**
- **Improve power chain**
- On-site generation
- **Design and M&O processes**



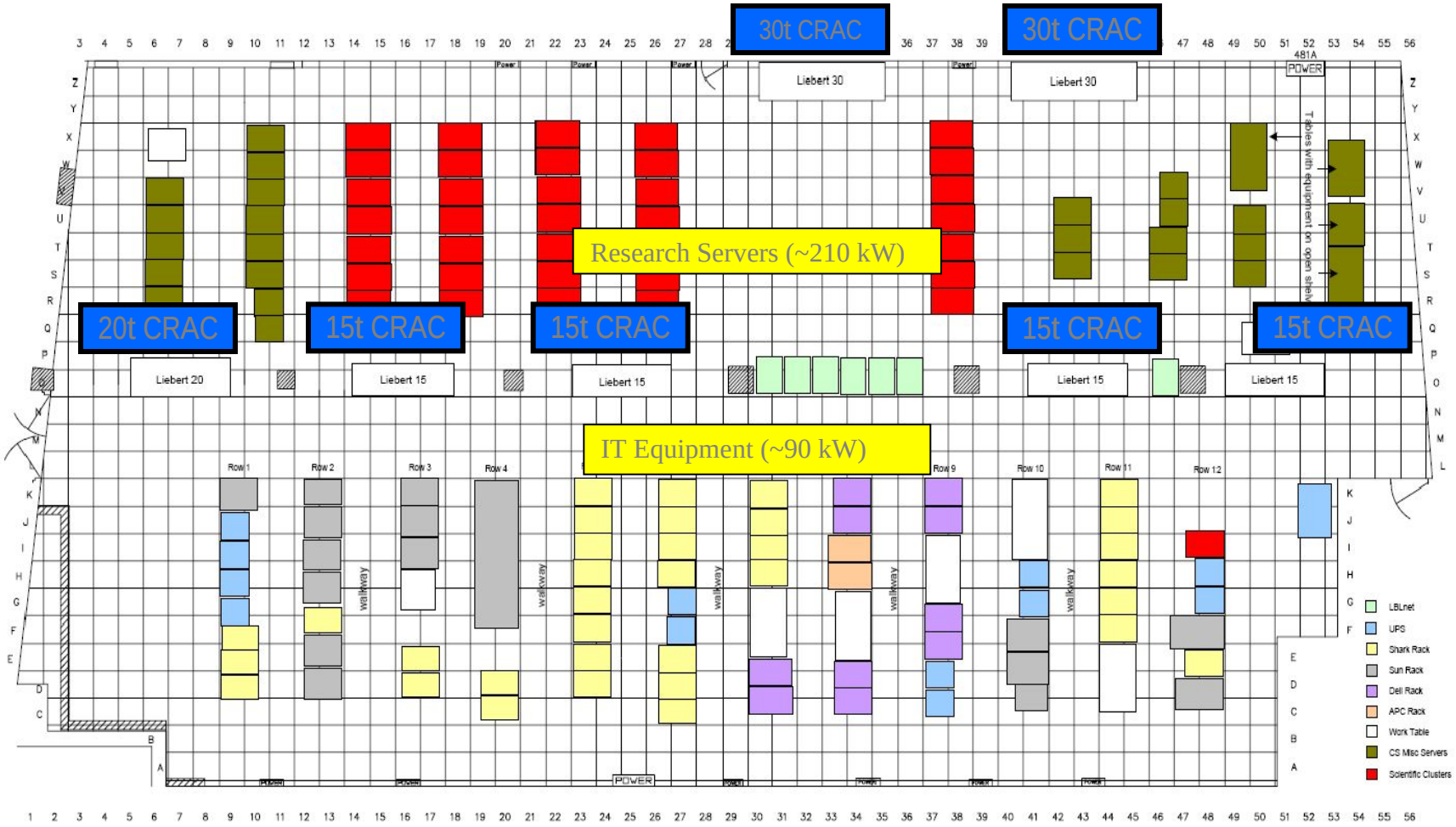
# Applying Best Practices at LBNL:

- Partnership between CIO, CS, and energy efficiency researchers
- Existing data centers relatively efficient
  - NERSC: .72 kW-IT/kW-total (taking advantage of central plant)
  - 50B-1275: .59 - .64 kW-IT/kW-total (tower cooled CRACs)
- Increased efficiency frees up needed “capacity”
- Leveraging data centers as test beds to create an impact beyond Berkeley Lab
- Working with vendors to develop new products and strategies

# Air Management:

- Typically, much more air is circulated through computer room air conditioners than is required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Improve isolation of hot and cold “aisles”
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity

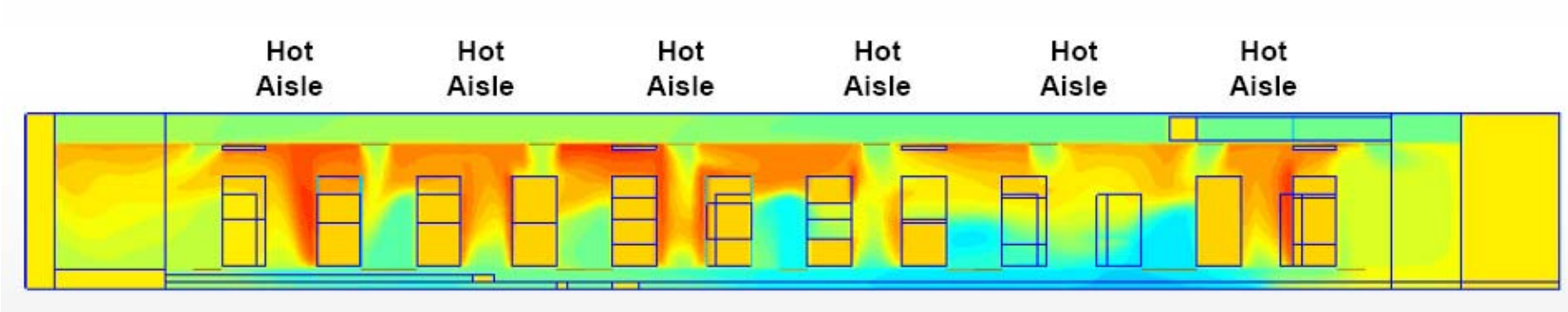
# Air Management Improvements in LBNL 50B-1275 Data Center (layout September 2007)

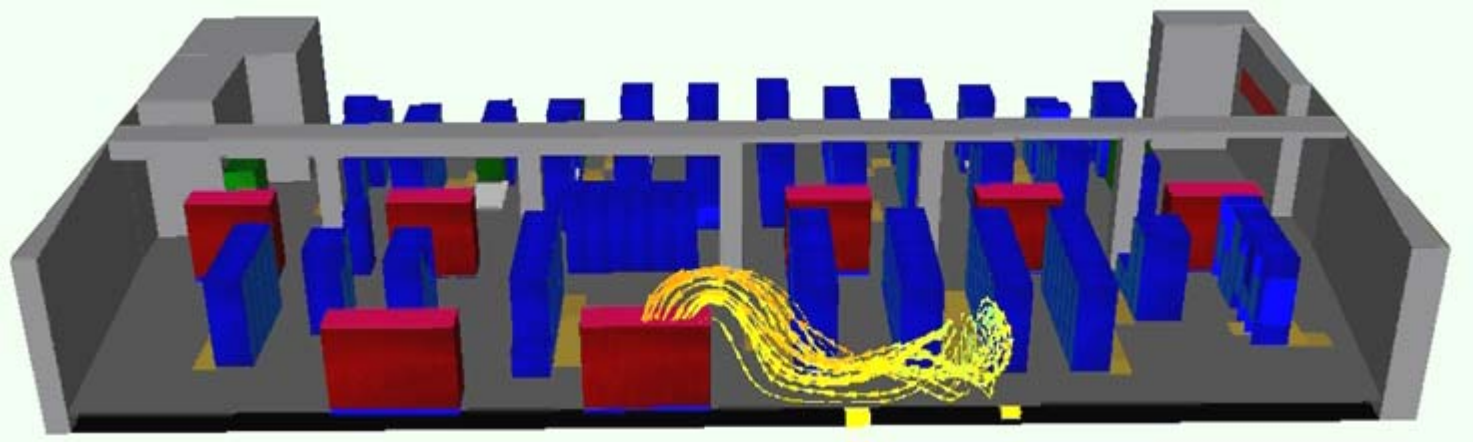


# Air Management Assessment Effort:

- Performed CFD
- Deployed wireless monitoring system
- Identified opportunities for improvement
  - Enforce hot aisle/cold aisle arrangement
  - Use blanking panels
  - Improve airflow and under floor pressure by tuning floor tiles (e.g. reduced number of perforated tiles)
  - Reduce mixing and short circuits
  - convert overhead plenum from supply to hot-air return
  - CRAC intakes extended into overhead

# Visualization Using CFD:

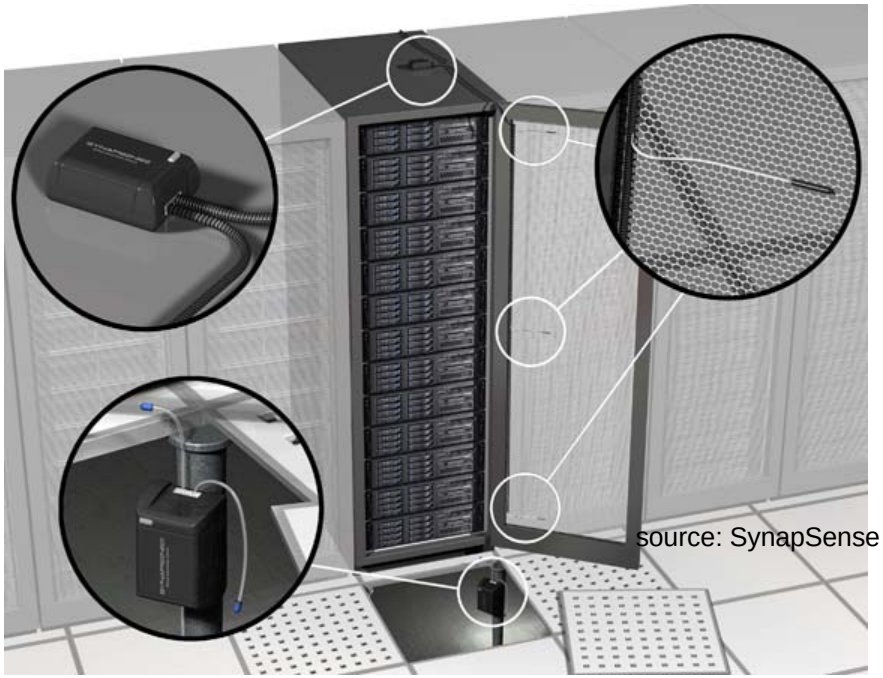


Images: ANCIS

# Wireless Environmental Monitoring:

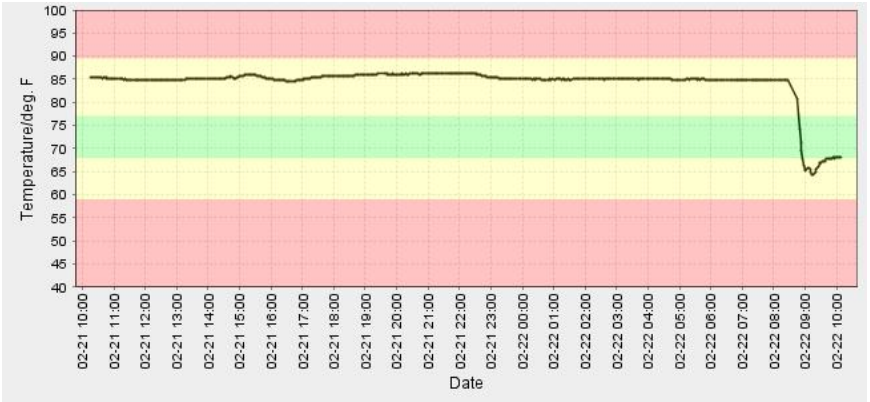
- Most operators lack visibility into data center environment
  - Can’t effectively manage the facility
- SynapSense wireless sensor network installed
  - 300 monitoring points (temperature, humidity, under-floor pressure, current)
- Air management now based on empirical data, not intuition


source: SynapSense

# Results: Blanking Panels

- One blanking panel added and temperature dropped ~20°
- impact of other best practices confirmed
  - eliminate leaks in floor
  - improve air management

top of rack

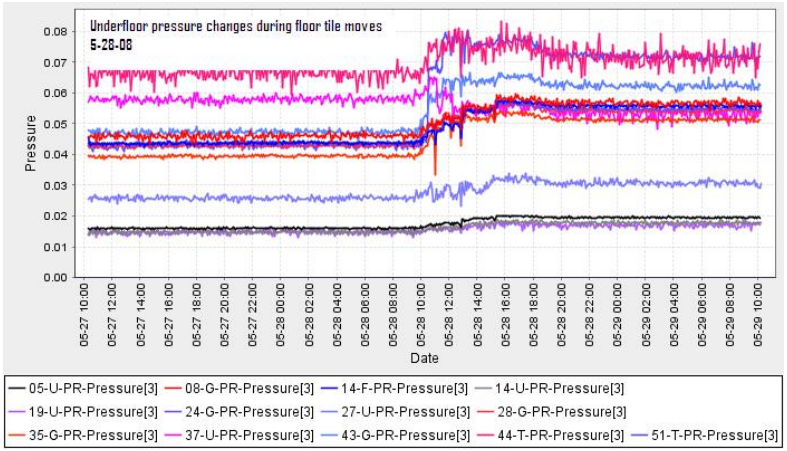



middle of rack

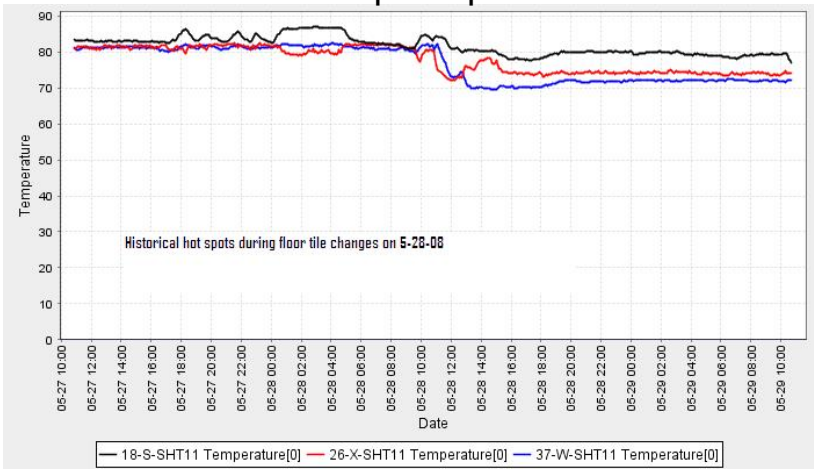
# Results: Tune Floor Tiles

- Too many permeable floor tiles
- if airflow is optimized,
  - under-floor pressure ↑
  - rack-top temperatures ↓
  - data center capacity grows
- Measurement and visualization assisted tuning process

under-floor pressures




rack-top temperatures



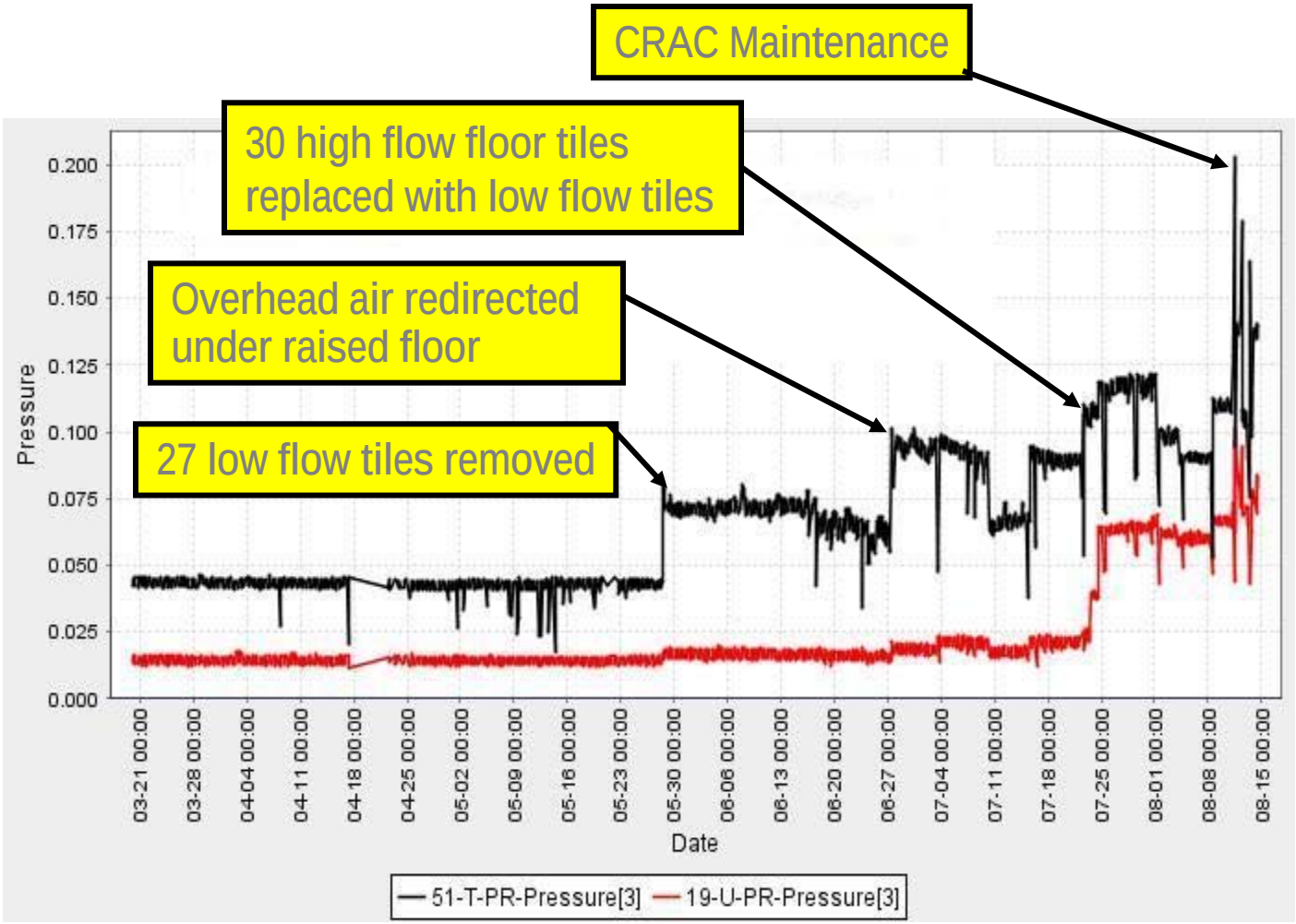
# Improve Air Management:

- Overhead plenum converted from supply to hot-air return
- CRAC intakes extended into overhead
- Return registers placed over hot aisle


Before

After

# Documenting Progress

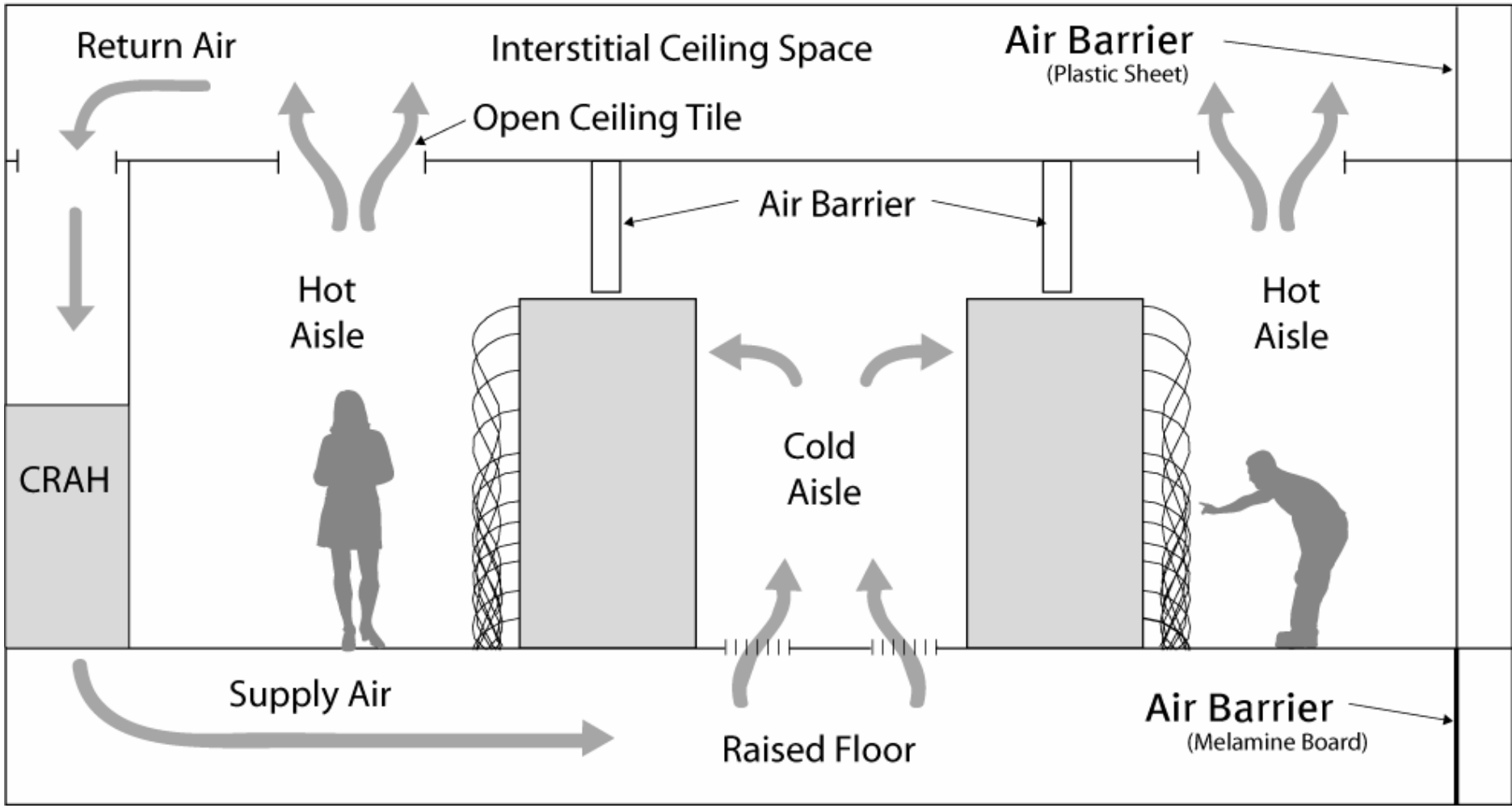



5 months of floor pressure management

# Results: Air Management Project (so far)

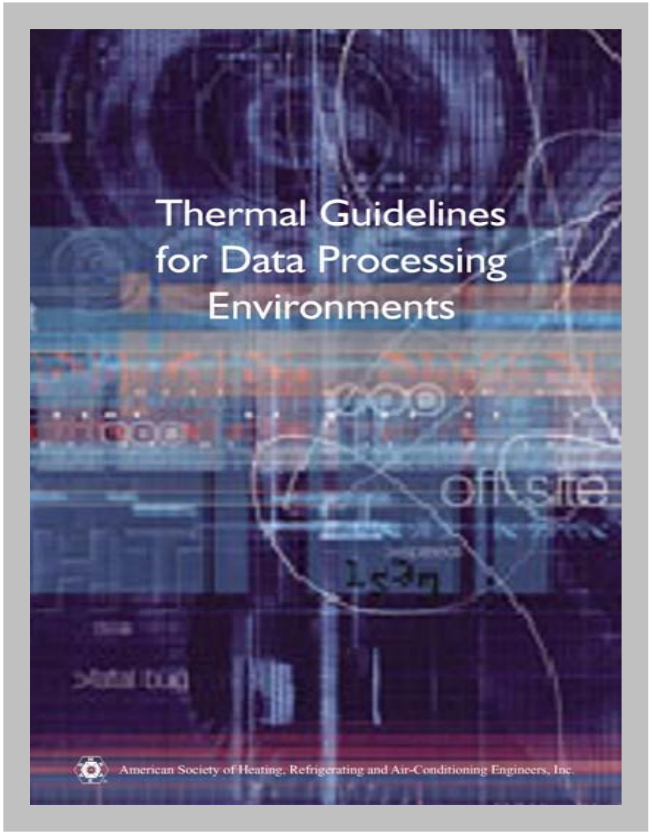
- 21% increase (~100kW) in IT load
- CRAC unit set points 3°F warmer
- Fewer hot spots
- (1) 15 ton CRAC unit turned off
- (1) extra 15 ton CRAC unit on-line but redundant
- Wireless sensor network enables operations to monitor and fine tune changes
- Next step:
  - Curtains to improve isolation
  - Integrated CRAC unit control upgrade

# Improve Air Management:

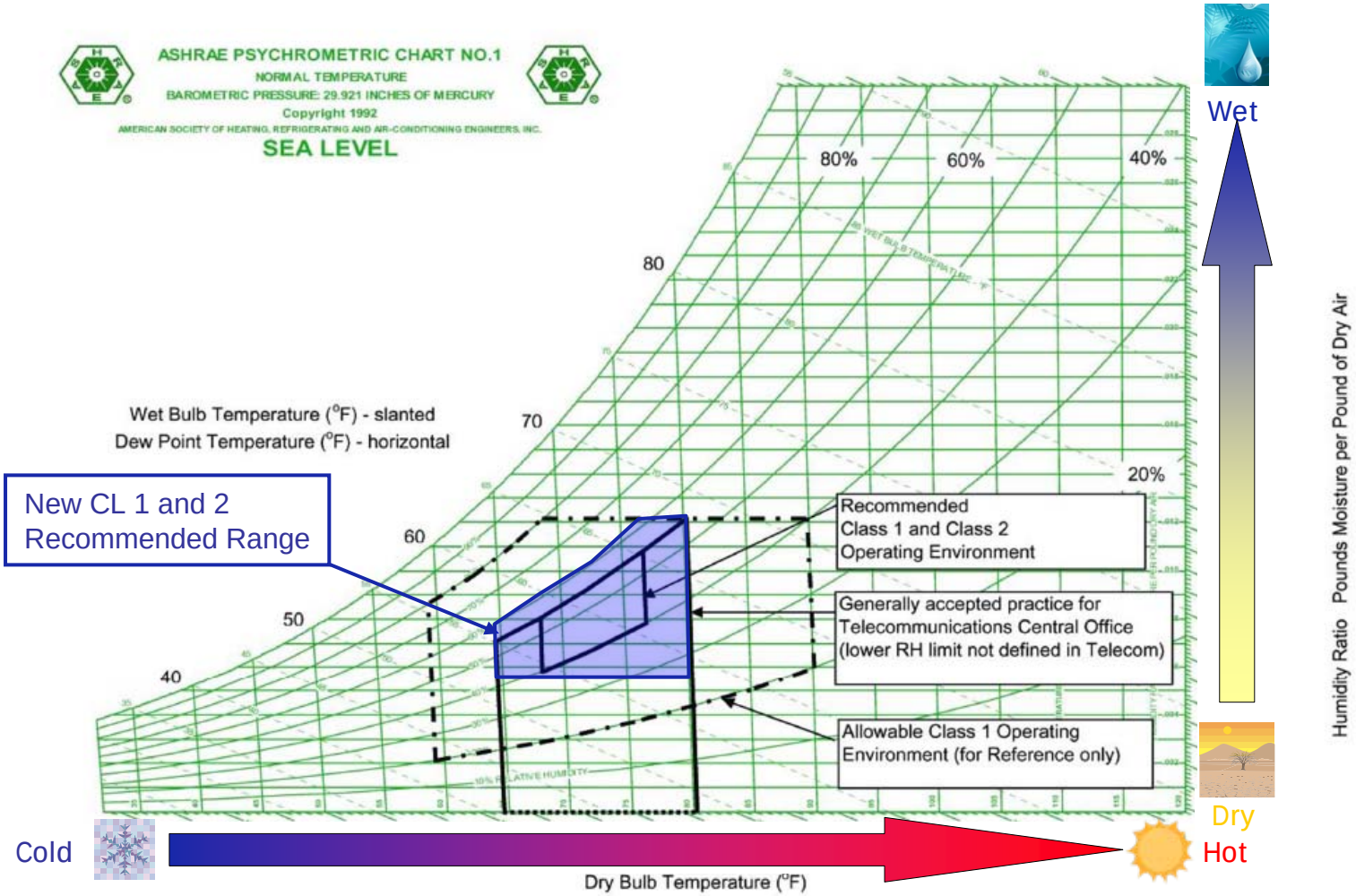


# Environmental Conditions

- Use ASHRAE Recommended and Allowable ranges of temperature and humidity



# Design conditions at the inlet to IT equipment



# Use Free Cooling:

- Water-side Economizers
  - No contamination question
  - Can be in series with chiller
- Outside-Air Economizers
  - Can be very effective (24/7 load)
  - Must consider humidity
- Let’s get rid of chillers in data centers

# Free Cooling – Liquid Based

- Infrastructure installed in 2008 for liquid cooling in 50B-1275
- Cooled with tower only or chiller assisted
  - Both options significantly better than existing liquid cooled (DX) CRAC units

# Improve Humidity Control:

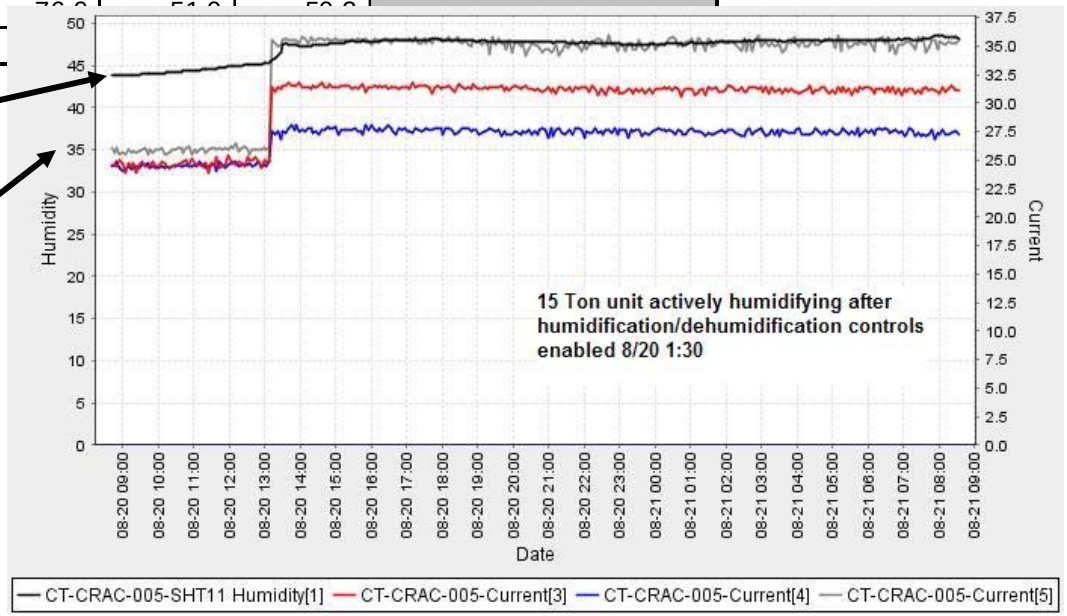
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
  - Medium-temperature chilled water
  - Humidity control at make-up air handler only
- Use ASHRAE allowable RH and temperature
- Eliminate equipment fighting
  - Coordinate controls on distributed AHUs

# The Cost of Unnecessary Humidification in 50B-1275

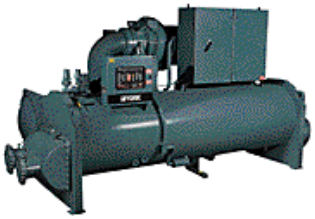
| | Visalia Probe | | | CRAC Unit Panel | | | |
|---|---|---|---|---|---|---|---|
| | Temp | RH | Tdp | Temp | RH | Tdp | Mode |
| AC 005 | 84.0 | 27.5 | 47.0 | 76 | 32.0 | 44.1 | Cooling |
| AC 006 | 81.8 | 28.5 | 46.1 | 55 | 51.0 | 37.2 | Cooling & Dehumidification |
| AC 007 | 72.8 | 38.5 | 46.1 | 70 | 47.0 | 48.9 | Cooling |
| AC 008 | 80.0 | 31.5 | 47.2 | 74 | 43.0 | 50.2 | Cooling & Humidification |
| AC 010 | 77.5 | 32.8 | 46.1 | 68 | 45.0 | 45.9 | Cooling |
| AC 011 | 78.9 | 31.4 | 46.1 | 70 | 43.0 | 46.6 | Cooling & Humidification |
| | | | | | | | |
| Min | 72.8 | 27.5 | 46.1 | 55.0 | 32.0 | 37.2 | |
| Max | 84.0 | 38.5 | 47.2 | | | | |
| Avg | 79.2 | 31.7 | 46.4 | | | | |

Humidity up 3%

CRAC power up 28%

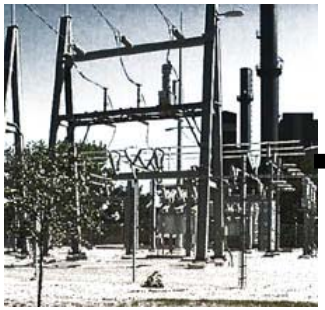


# Electricity Flows in Data Centers



HVAC system

local distribution lines



lights, office space, etc.

uninterruptible load

to the building, 480 V

UPS

PDU

computer racks

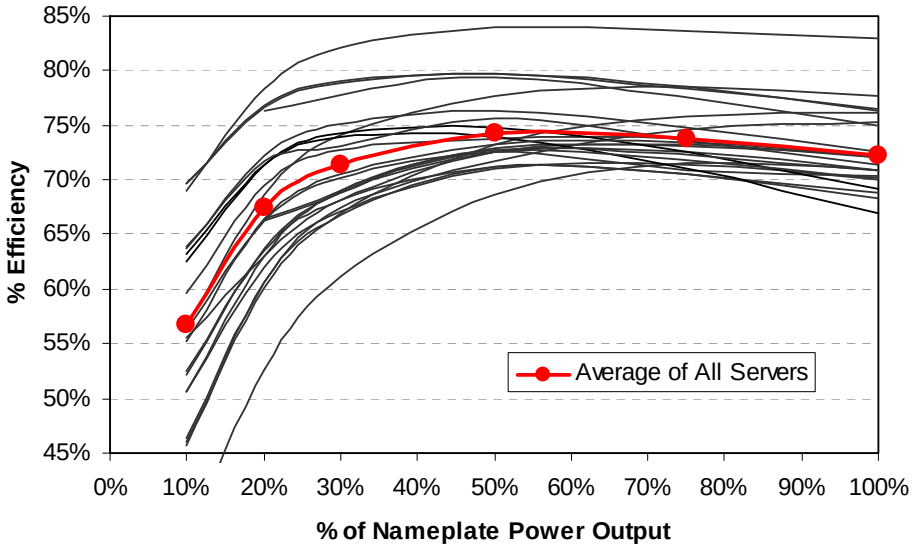
computer equipment

backup diesel generators

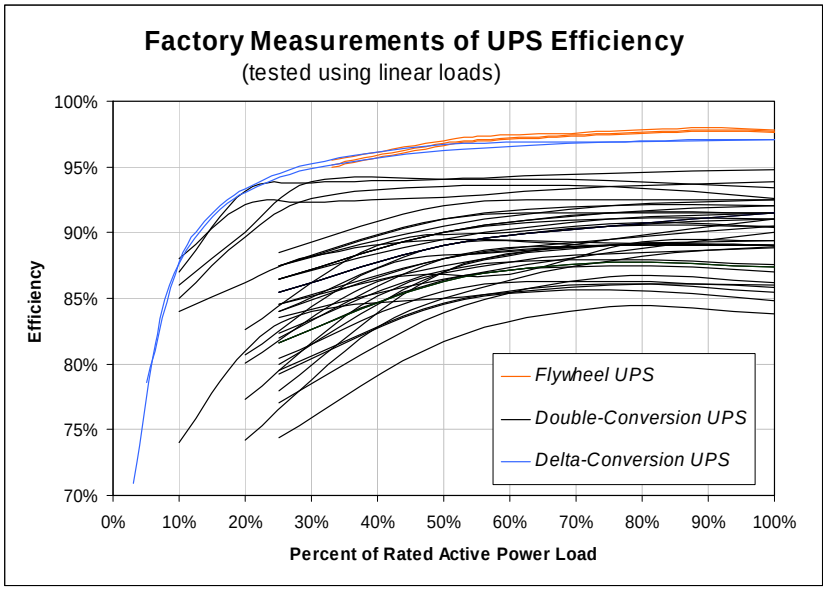
UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

# Specify Efficient Power Supplies and UPSs

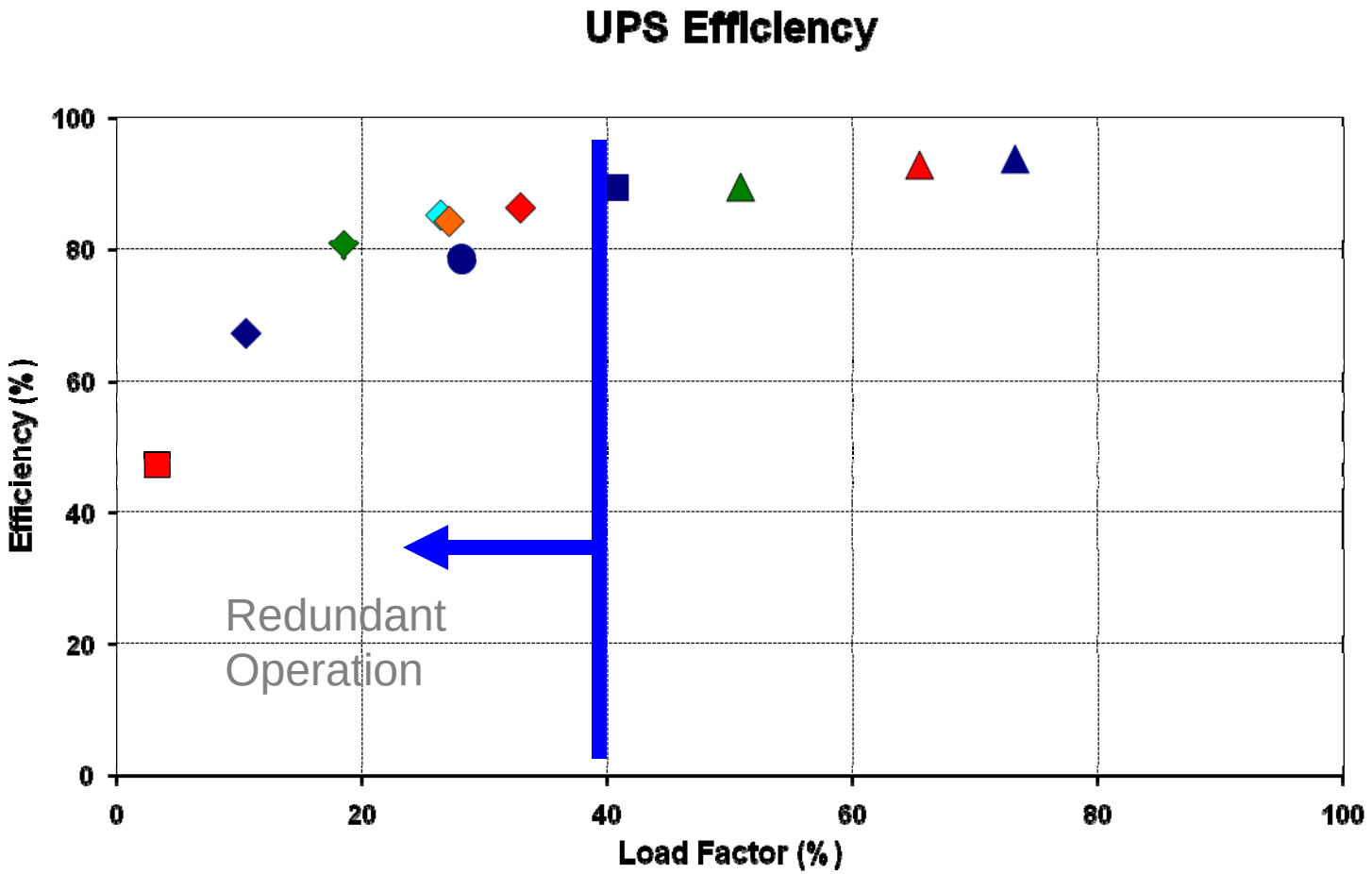



**Power supplies in IT equipment generate much of the heat. Highly efficient supplies can reduce IT equipment load by 15% or more.**




**UPS efficiency also varies**

# Measured UPS Efficiency



# Redundancy

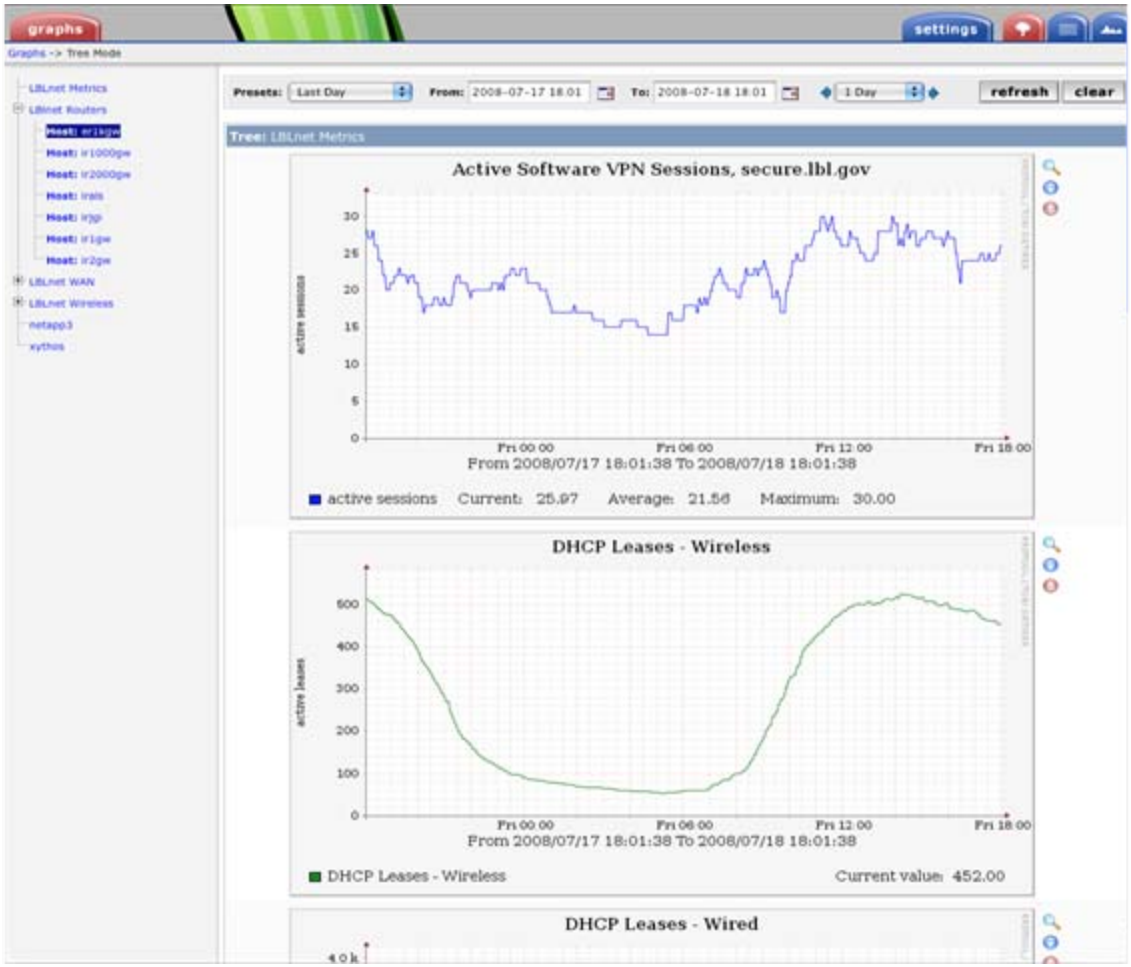
- Understand what redundancy costs – is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Redundancy in electrical distribution puts you down the efficiency curve
- LBNL minimizes use of redundant power supplies and size of UPS

# LBNL Wireless Monitoring System:

- 300 point SynapSense wireless monitoring
  - Temperature, humidity, under-floor pressure, CRAC current
  - 1-2 day installation, easy redeployment
- For the first time, we have a detailed understanding of environmental conditions
  - Real-time and historical data
  - Remote console and alert notification
  - Quick reports and graphs from underlying database
  - Modules can also measure liquid flow, liquid presence, and particle count

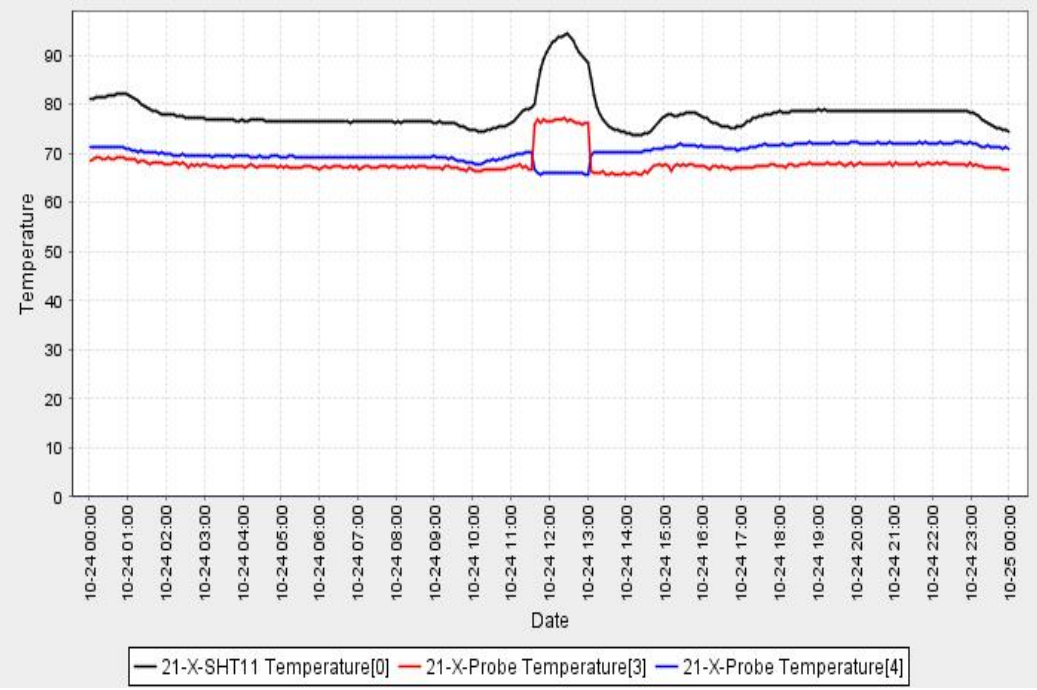
# The Importance of Visualization

- Systems & network administrators have tools for visualization
- Useful for debugging, benchmarking, capacity planning, forensics
- Data center facility managers have comparatively poor visualization tools



# Learning from the sensors

Rack top, middle and bottom temperature when cold aisle air flow obstructed




# Next Steps with SynapSense

- Integration of monitoring system with controls (Automatic staging of CRACs and Demand based resets of pressure and temperature)
- ‘Live Imaging’ heat-map animations
- Real time DCiE (data center infrastructure efficiency) calculation

Advice:

- Put together team of IT, Facilities and experienced consultants
- Benchmark energy and environmental performance
- Instrument and convert data to information
- Eat your spinach (blanking panels, leaks, CRAC maintenance)
- Keep an eye on emerging technologies (flywheel UPS, rack-level cooling, DC power)

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